PSYC401A/501A: Principles of Psychophysiology

Spring, 2008, Mondays, 3:00-5:50 p.m.
Room 304 Psychology

Syllabus

Online Syllabus:
http://www.u.arizona.edu/~jallen
Follow link to Courses

Administrivia

- Drops and Adds
- Overview of Syllabus
- Class Format

Substantive Topics

- General Definition and Interpretive Issues
- Review of studies that highlight the utility of a psychophysiological approach

- Note Book Chapter request:

http://www.library.arizona.edu/services/docdel/

General Issues

- Definition
- Scope
- Problems of inference
- Problems and Prospects for the field

Definition

- Darrow (1964) Presidential Address:
  - the science which concerns physiological activities which underlie or relate to psychic events
- Ax (1964) Opening Editorial, *Psychophysiology*

Psychophysiology is a research area which extends observation of behavior to those covert proceedings of the organism relevant to a psychic state or process under investigation and which can be measured with minimal disturbance to the natural functions involved. Modern psychophysiology is a response to the challenge inherent in the full realization of the complex nature of the human organism.

Psychophysiology provides a method for bringing both physiological and psychological aspects of behavior into a single field of discourse by which truly organismic constructs may be created.

- Stern (1964), also in the 1st issue of *Psychophysiology*

Definition

- Stern (1964), also in the 1st issue of *Psychophysiology*

I would like to offer as a working suggestion that any research in which the dependent variable is a physiological measure and the independent variable a "behavioral" one should be considered psychophysiological research

TABLE 1

	Independent variable	Dependent variable
Physiological psychology	Brain lesion	Learning—behavioral
	Brain stimulation	Performance
	Drug administration	Conditioning
	Diet manipulation	Food selection
	Auditory stimulation	Habituation of orienting response
	Vigilance experiment	EEG evoked response
Psychophysiology	Sleep deprivation	Background EEG
	Psychologic or psychiatric state (fear, anxiety, depression, etc.)	Conditionability of physiological system
	Dreaming	Physiological correlates

Yet he concludes… *"I wish our editor the best of luck in defining the scope of articles acceptable for our journal."*

Definition

- Darrow (1964):
  - the science which concerns physiological activities which underlie or relate to psychic events
- Cacioppo Tassinary & Berntson (2007):
  - the scientific study of social, psychological, and behavioral phenomena as related to and revealed through physiological principles and events in functional organisms
- Allen (2008, this very moment):
  - The use of a particular set of physiologically-based dependent or independent variables to gain insights into psychological questions; when done well, psychophysiological methods
    - provide an independent method
    - provide information that is not accessible through other psychological methods
- Distinguished from: Physiological psychology, Behavioral Neuroscience

Scope

"Classic Measures"

- Skin Conductance (level and response)
- Cardiac measures (heart rate, variability, contractility, both SNS and PNS measures, BP, plethysmography)
- Oculomotor and pupilometric measures
- Electromyographic activity
- Respiration
- Gastrointestinal activity
- Penile and vaginal plethysmography
- Electroencephalographic oscillatory measures (frequency domain EEG and sleep psychophysiology)
- Event-related brain potentials
- Event-related frequency changes

"Newer Measures"

- Hormonal and Endocrinological measures
- Immune function
- Functional neuroimaging
  - PET
  - fMRI
  - Optical Imaging
- MEG

Manipulations

- Classical Biofeedback
- Rapid Transcranial Magnetic Stimulation

Thematic x Systemic Psychophysiology

	Cognitive psychophysiology	Developmental psychophysiology	Clinical psychophysiology	Social psychophysiology	Applied psychophysiology
Electrodermal psychophysiology	fMRI duing emotion				Lie Detection
Cardiovascular psychophysiology			Cardio effects prejudice		
Electroencephalo-graphic psychophysiology		EEG Asym Inhibited kids			
Electro-myographic psychophysiology					
Hemodynamic psychophysiology	fMRI duing emotion				
Etc…					

Problems of Inference: Correlate Vs Substrate

- Is observed physiological activity a substrate of observed behavior? BEWARE
- Helpful Criteria
  - Is Φ necessary for behavior?
  - If Φ removed, would behavior be altered?
- But ultimately, not easily resolved

A scientific theory is a description of causal interrelations. Psychophysiological correlations are not causal. Thus in scientific theories, psychophysiological correlations are monstrosities. This does not mean that such correlations have no part in science. They are the instruments by which the psychologist may test his theories. (Gardiner, Metcalf, & Beebe-Center, 1937, p. 385)

Problems of Inference

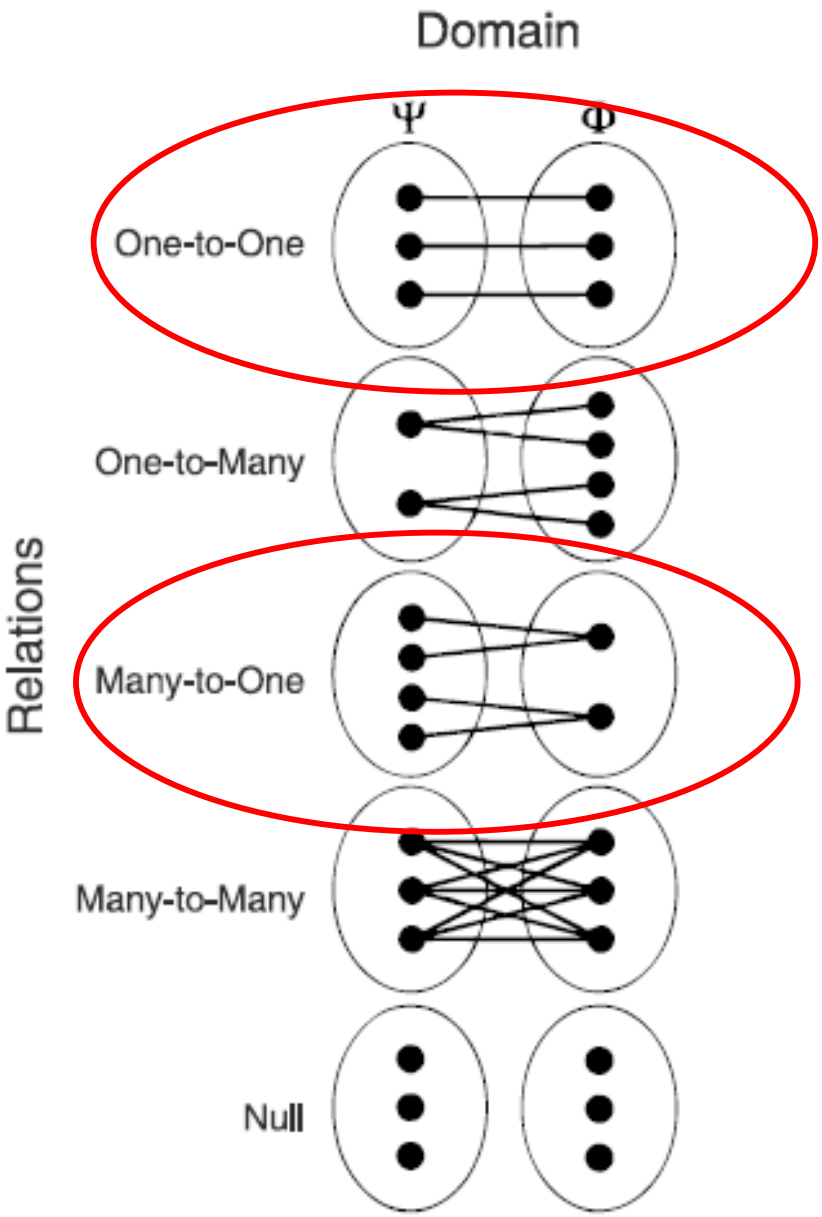


Figure 2. Possible relationships between elements in the psychological (Ψ) and physiological (Φ) domains.

From Cacioppo, Tassinary, & Berntson, 2000, 2007

Only these types of relationships would allow a formal specification that psychological elements are a function of specific physiological elements

Reducing the Complexity

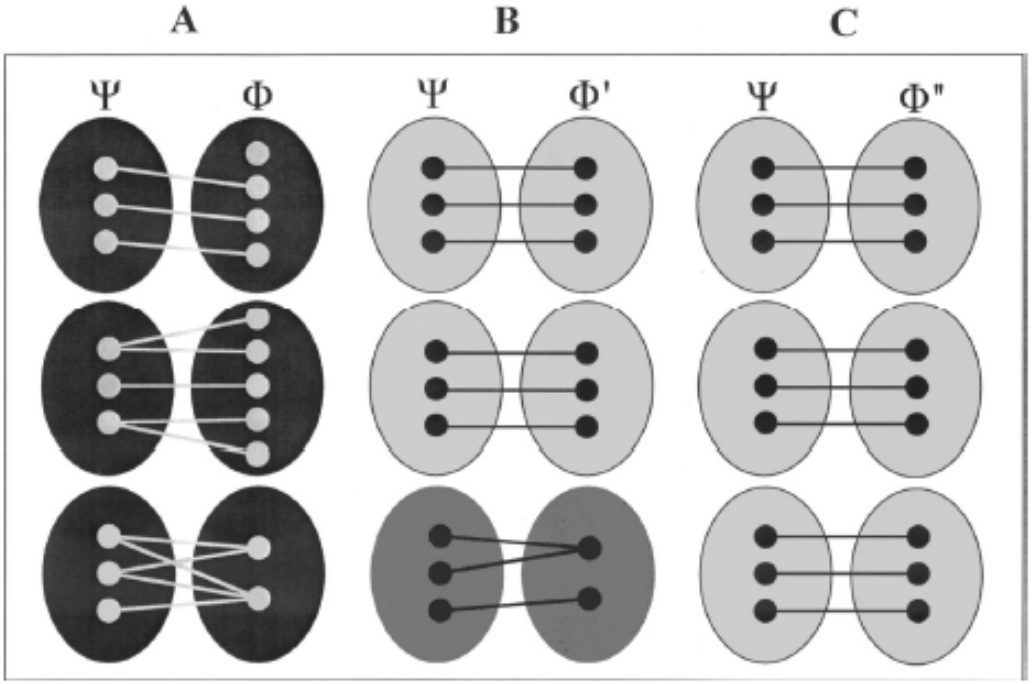


Figure 1. Depiction of logical relations between elements in the psychological (Ψ) and physiological (Φ) domains. Left panel: Links between the psychological elements and individual physiological responses. Middle panel: Links between the psychological elements and the physiological response pattern. Right panel: Links between the psychological elements and the profile of physiological responses across time.

From Cacioppo, Tassinary, & Berntson, 2000

Typical Scenarios

- Typical structure/assumption of psychophysiological or imaging study:
  - $P(\Phi|\Psi) > 0$
- Typical structure/assumption of biofeedback study:
  - $P(\Psi|\Phi) > 0$
- Typical hunt for "markers" or biological substrate
  - Study begins $P(\Phi|\Psi) > 0$
  - Desirable (but often invalid) inference
    - $P(\Psi|\Phi) > 0$
    - Only valid given 1:1 relationship of Ψ and Φ
  - Use complementary approaches; e.g.,
    - fMRI = $P(\Phi|\Psi)$
    - Lesion = $P(\Psi|\Phi)$

The Taxonomy of Φ and Ψ

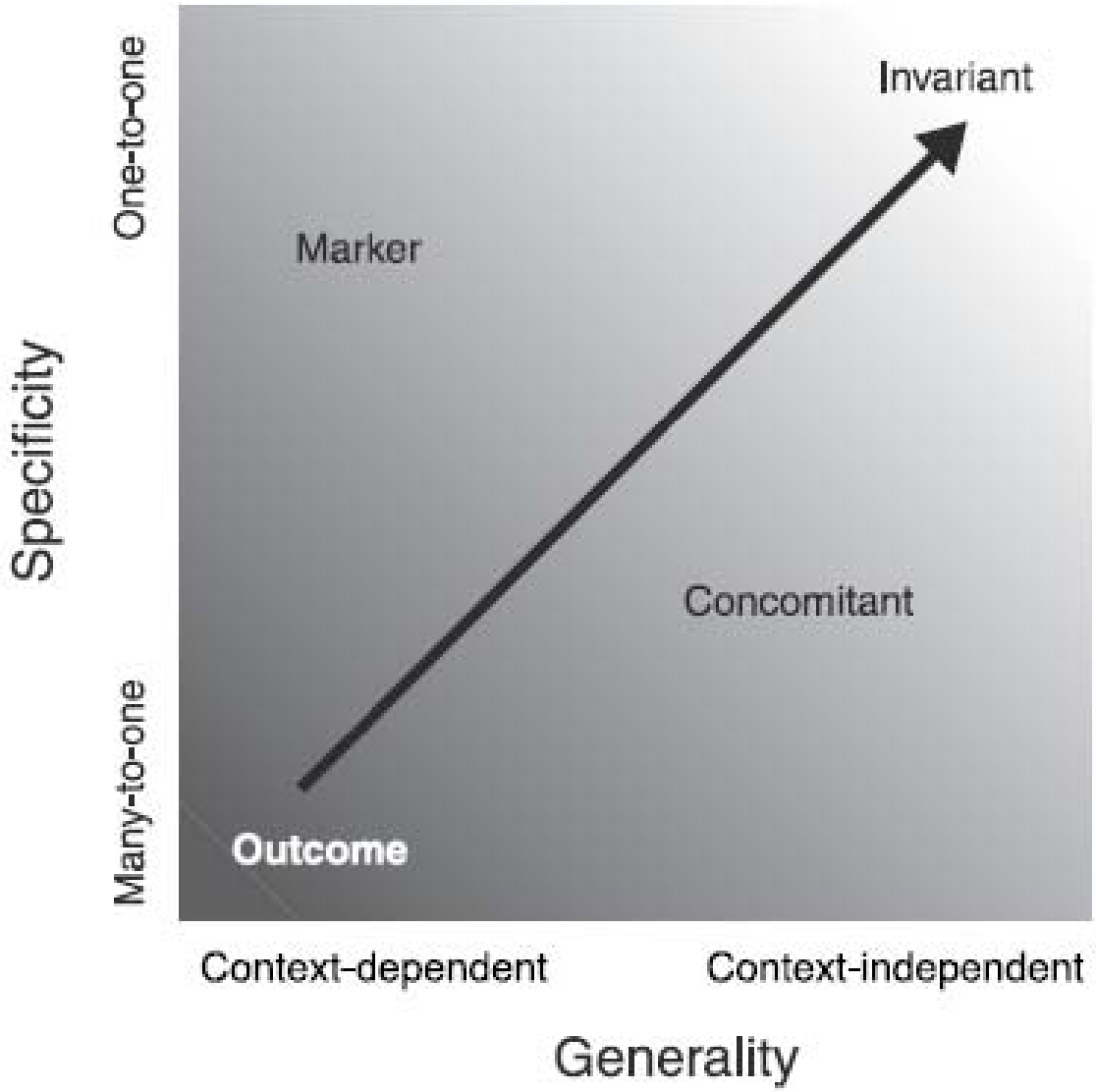
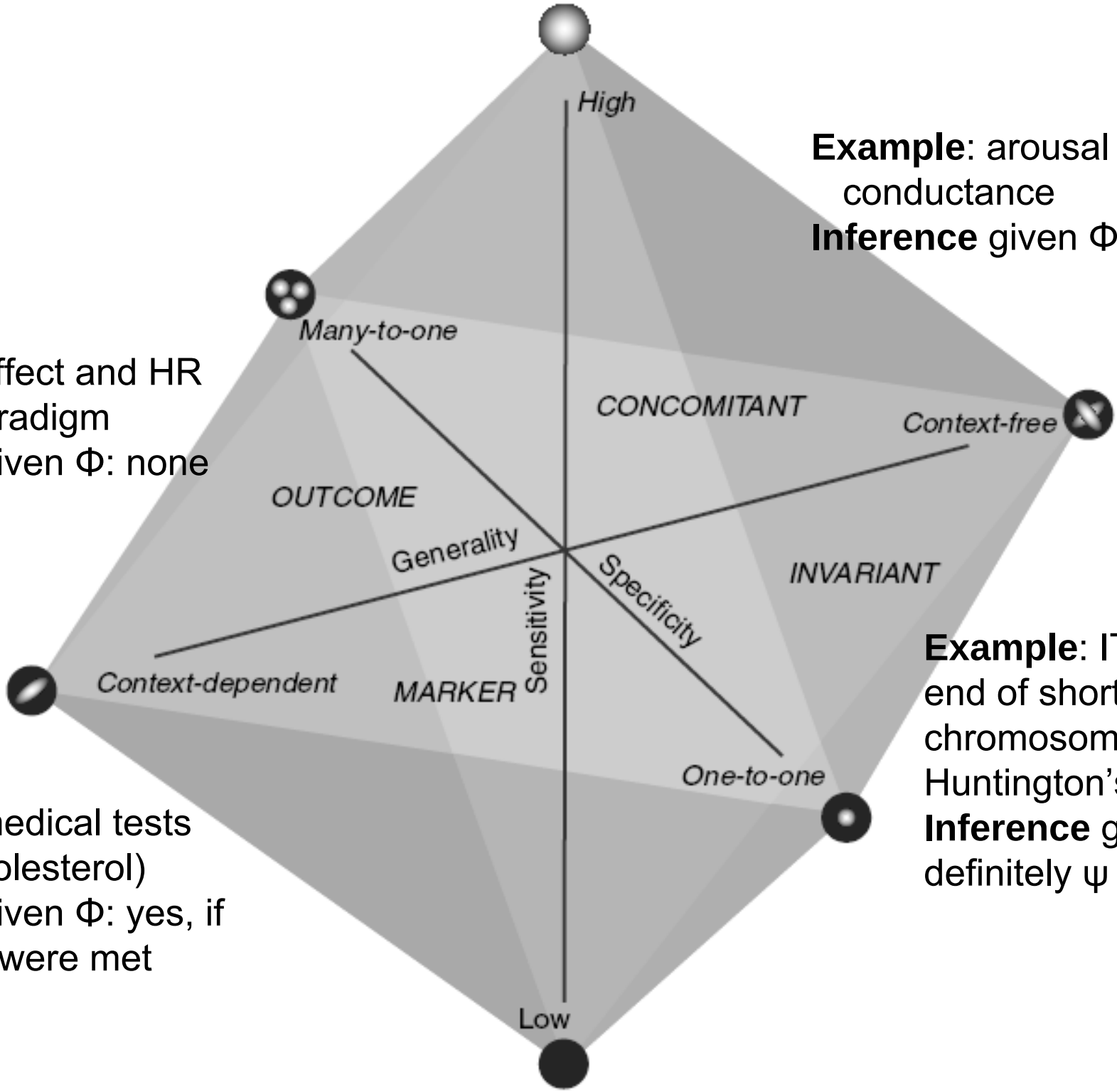


Figure 3. Taxonomy of psychophysiological relationships.

From Cacioppo, Tassinary, & Berntson, 2000



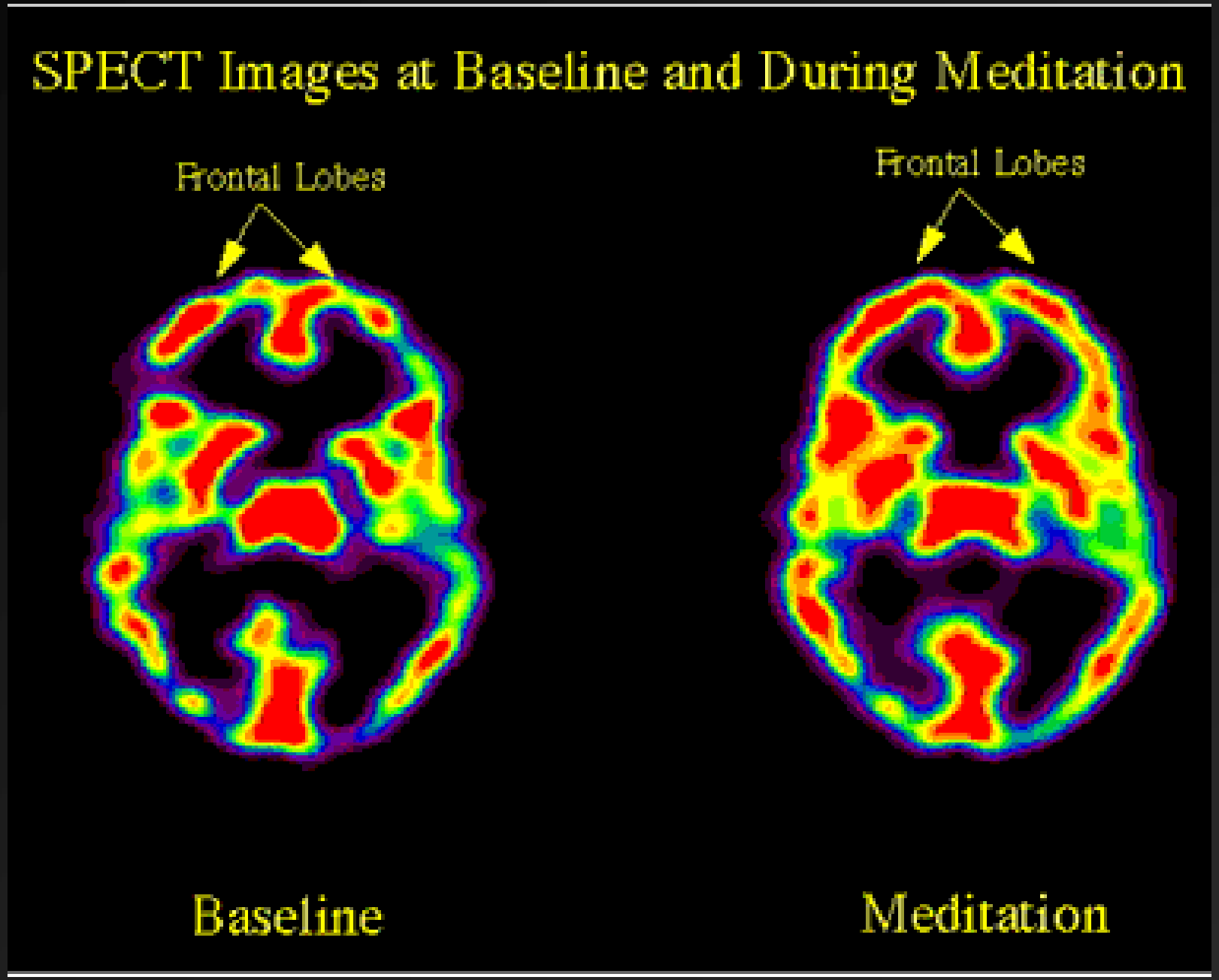
Example: arousal and skin conductance
Inference given Φ: none

Example: affect and HR in IAPS paradigm
Inference given Φ: none

Example: IT15 near end of short arm chromosome 4 and Huntington's
Inference given Φ: definitely ψ

Example: medical tests (fasting cholesterol)
Inference given Φ: yes, if conditions were met

The Inference Problem -- Illustrated



d'Aquili and Newberg (1993) "Religious and Mystical States: A Neuropsychological Substrate" (Zygon 28: 177-200, 1993).

An Improvement – but still just an outcome

Azari et al. (2001). Neural correlates of religious experience. *European Journal of Neuroscience*, *13*, 1649-1652.

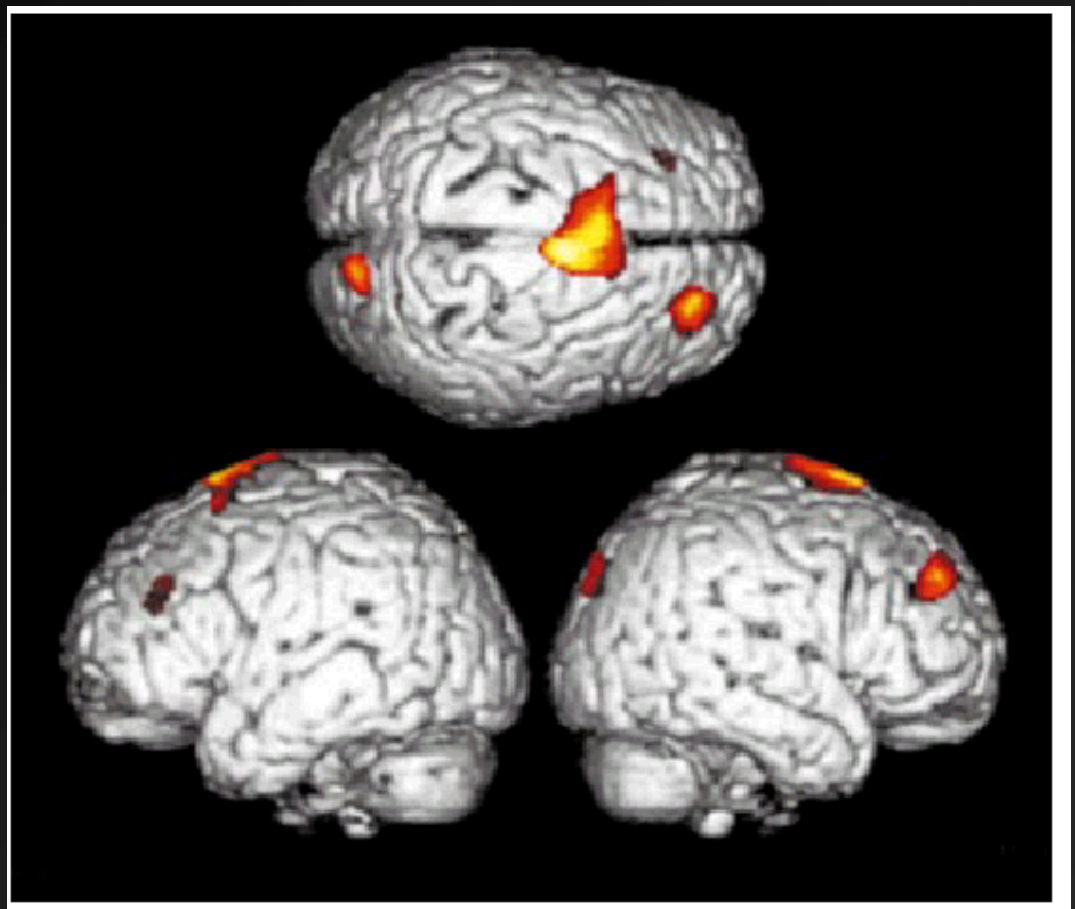


FIG. 1. Significant activations for the contrast 'religious-recite' vs. 'rest' in religious subjects, rendered onto canonical T1-weighted image of SPM97d ($P < 0.001$, uncorrected for multiple comparisons) (see also Table 2). Shown are the left, dorsal and right view of the brain. Scans for each subject were realigned and spatially normalized onto the PET template, and smoothed using an isotropic Gaussian kernel with FWHM set at 20 mm. The SPM grey matter threshold was set to its default value. For task comparisons, an ANCOVA (analysis of covariance) model was fitted to the data for each voxel.

Yet Another Example!

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NeuroImage

NeuroImage 20 (2003) 2119–2125

www.elsevier.com/locate/ynimg

One brain, two selves

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Abstract

Having a sense of self is an explicit and high-level functional specialization of the human brain. The anatomical localization of self-awareness and the brain mechanisms involved in consciousness were investigated by functional neuroimaging different emotional mental states of core consciousness in patients with Multiple Personality Disorder (i.e., Dissociative Identity Disorder (DID)). We demonstrate specific changes in localized brain activity consistent with their ability to generate at least two distinct mental states of self-awareness, each with its own access to autobiographical trauma-related memory. Our findings reveal the existence of different regional cerebral blood flow patterns for different senses of self. We present evidence for the medial prefrontal cortex (MPFC) and the posterior associative cortices to have an integral role in conscious experience.

"Our data confirm the emergence of conscious versus unconscious experience in the neural network of superior and inferior parietal lobule, left occipital cortex, precuneus, and frontal brain areas including BA 6 and BA 10." page 2124

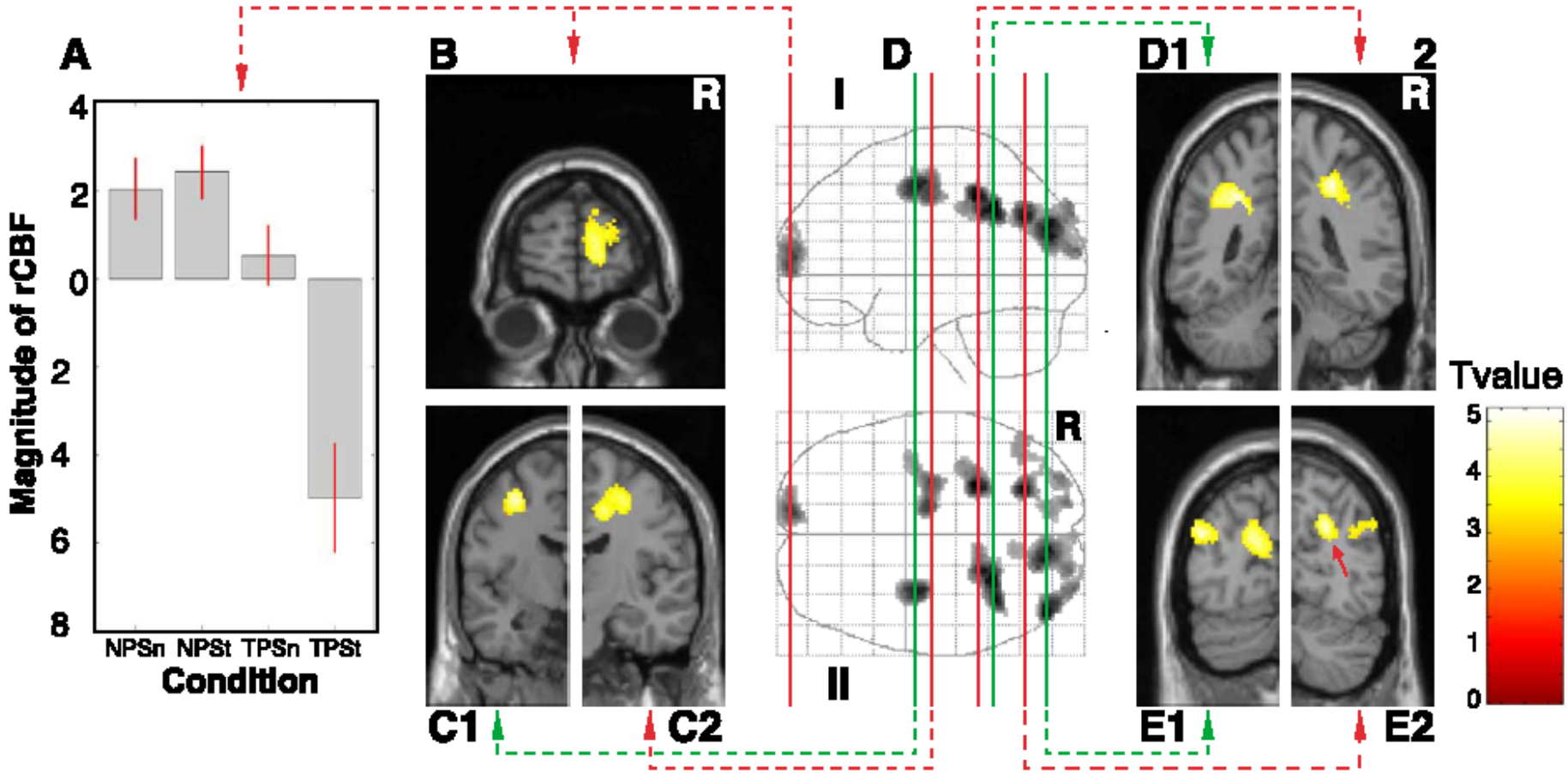


Fig. 1. Brain regions showing a significant response on the autobiographical trauma-related script in Neutral Personality State (NPS) as compared to Traumatic Personality State (TPS). (A) Mean regional cerebral blood flow (rCBF) changes at the voxel of maximum activation ($x = 12$, $y = 63$, $z = 8$) in the right medial prefrontal cortex (MPFC, Brodmann's area (BA) 10) for the four conditions of our study, i.e., exposure to a neutral (minor character n) and trauma (minor character t) memory script while remaining in NPS or TPS. Bars represent standard errors. The response shown is typical for the areas depicted in parts B through E. (B, C, D, E) Coronal slices of the brain regions involved in the functional neural network of autobiographical self-awareness. Slices are shown at the level of the most significant activation: part B (right BA 10; $x = 12$, $y = 63$, $z = 8$), C1 (left BA 6; $x = -30$, $y = -4$, $z = 46$), C2 (right BA 6; $x = 30$, $y = -11$, $z = 47$), D1 (left BA 7/40; $x = -24$, $y = -45$, $z = 37$), D2 (right BA 7/40; $x = 28$, $y = -37$, $z = 42$), E1 (left BA18/precuneus; $x = -8$, $y = -76$, $z = 24$ and BA19; $x = -44$, $y = -76$, $z = 30$), and E2 (right BA18/precuneus; $x = 26$, $y = -62$, $z = 33$ (as indicated with the small red arrow)). See also Table 1. (I and II) Parts I (sagittal view) and II (transaxial view) show the statistical parametric maps (the glass brains) of significant areas. Red and green lines represent the various brain levels, where the activations depicted in parts B through E of the figure have their peak significance value. Red lines are used for clusters located in the right hemisphere, while green lines are used for clusters in the left hemisphere. The letter R indicates the right side of the brain.

Problems and Prospects for Psychophysiology

Problems/Challenges

- Interpretive ambiguity
- Time resolution and time courses of various systems/measures differ substantially
- Spatial resolution
- What is the functional significance of the observed physiological measure?

Problems and Prospects for Psychophysiology

Prospects

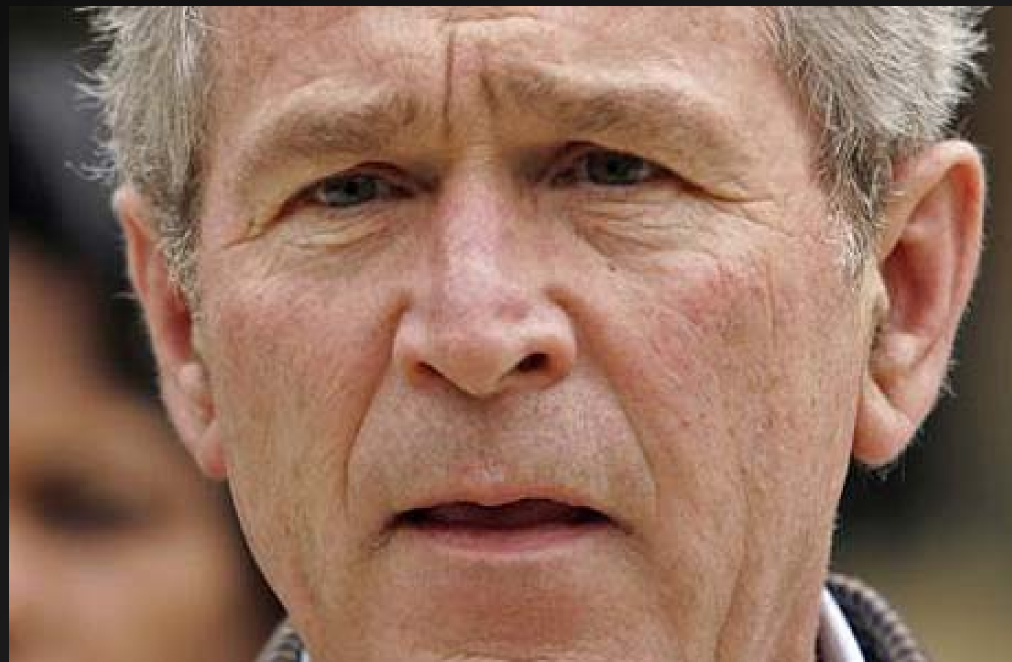
- Non-invasive
- Measures of real-time information
- May be sensitive to things that we ourselves cannot be
- Ideally suited for populations that have limited verbal/cognitive capacity
- May tap function at roughly the proper level of the nervous system to be useful to psychological investigators
- Psychophysiology is now more integrated into psychology as a whole -- you will see it in "nonspecialty" journals
- More and more “canned” packages make it accessible to the novice, but novices need advice and consultation!
- Even though there will always be newer technologies (e.g., PET, SPECT, MEG/SQUID, MRI, Functional MRI, etc.), traditional psychophysiology
  - Has generally excellent sreal-time resolution
  - Is flexible
  - Is cost-effective
  - Can be integrated with many of the newer technologies
  - Principles generalize across many measures
- When you tell folks at a party that you are a psychophysiologist rather than a psychologist, you are spared hearing the history of peoples' family pathology

A few selected studies to highlight the utility of a psychophysiological approach

- Bauer (1984): Prosopagnosia
- Öhman & Soares (1993): Phobias
- Speigel (1985): Hypnosis
- Deception Detection studies
- Brain-Computer Interfaces for assisted communication
- Dikman & Allen (2000): Psychopathy

Bauer (1984): Neuropsychologia

- Prosopagnosia
- Administered a version of the Guilty Knowledge Test (GKT)
  - As administered to the prosopagnosic patient
    - Set A consisted of 10 photographs of very famous folks; Set B consisted of 8 family members
    - During the display, five choices for the correct name were presented auditorially



George

Bauer (1984): Neuropsychologia

- Results
  - Patient naming: 0/10 famous faces, 0/8 family members
  - Controls naming = 9/10 famous, 0/8 of patient's family members
  - Electrodermally, patient produced largest SCR to correct alternative
    - for 60% of famous faces (controls 80%, *ns* difference),
    - for 62.5% of family members (controls 37.5%)
- Conclusions
  - Dissociation between psychophysiological and behavioral measures -- psychophysiology told us something that the patient could not
  - Patient can, at an autonomic level, properly identify faces
    - *viz.* that "prosopagnosia involves a functional defect not at the perceptual level itself, but at a stage of processing where adequate perceptual information is utilized in complex decisions about the stimulus identity" (p.463)

Öhman & Soares (1993)
Journal of Abnormal Psychology

- Hypothesize that information processing of the phobic stimulus is rooted in archaic information processing mechanisms outside of the control of conscious intentions
- Use a CS+/CS- paradigm for fear-relevant and fear-irrelevant stimuli
  - Fear relevant is snake/spider; irrelevant is a flower or mushroom
  - During acquisition trials, CS+ is shocked, CS- is not
  - This leads to larger SCR to CS+ than CS- , and when stimuli are presented above threshold (with awareness), no difference between fear-relevant and fear-irrelevant
  - After acquisition, masked presentations (30 msec, followed by 100 msec mask)
  - Electrodermally, masking effectively eliminates the difference between CS+ and CS- for fear-irrelevant stimuli, but the difference between CS+/CS- is preserved for fear-relevant stimuli

Öhman & Soares (1993)
Journal of Abnormal Psychology

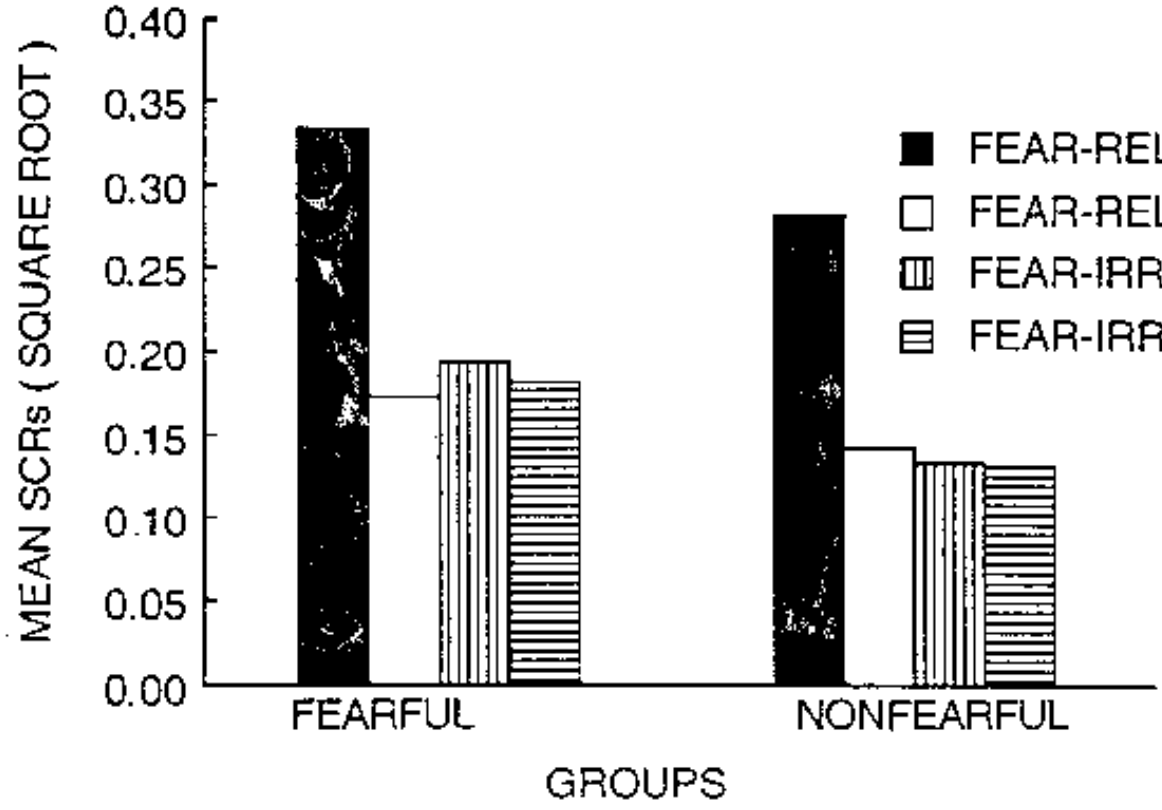


Figure 1. Mean skin conductance responses (SCRs) (square-root transformed) to fear-relevant (snakes, spiders, and rats) or fear-irrelevant (flowers and mushrooms) stimuli previously followed (CS+) or not followed (CS−) by an electric shock unconditioned stimulus among the fearful and nonfearful groups of subjects during extinction.

Öhman & Soares' Conclusions

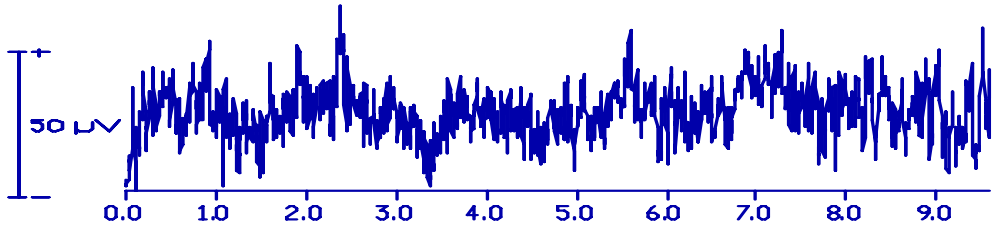
- Fear conditioning to nonprepared stimuli may involve conscious mechanisms
- Fear conditioning to prepared stimuli may be possible through mechanisms outside of conscious/controlled information processing
- Latter system may be fast and sensitive to danger cues
- May also explain why exposure therapy is critical to decrease the autonomic responses

Speigel, Cutcomb, Ren, & Pribram. (1985) Journal of Abnormal Psychology

- Hypnosis
  - individual difference variable,
  - assessed via responsiveness to suggestions
- Two issues recurrently arise in hypnosis:
  - (1) Do the effects have veracity?
  - (2) If so, how are they accomplished?

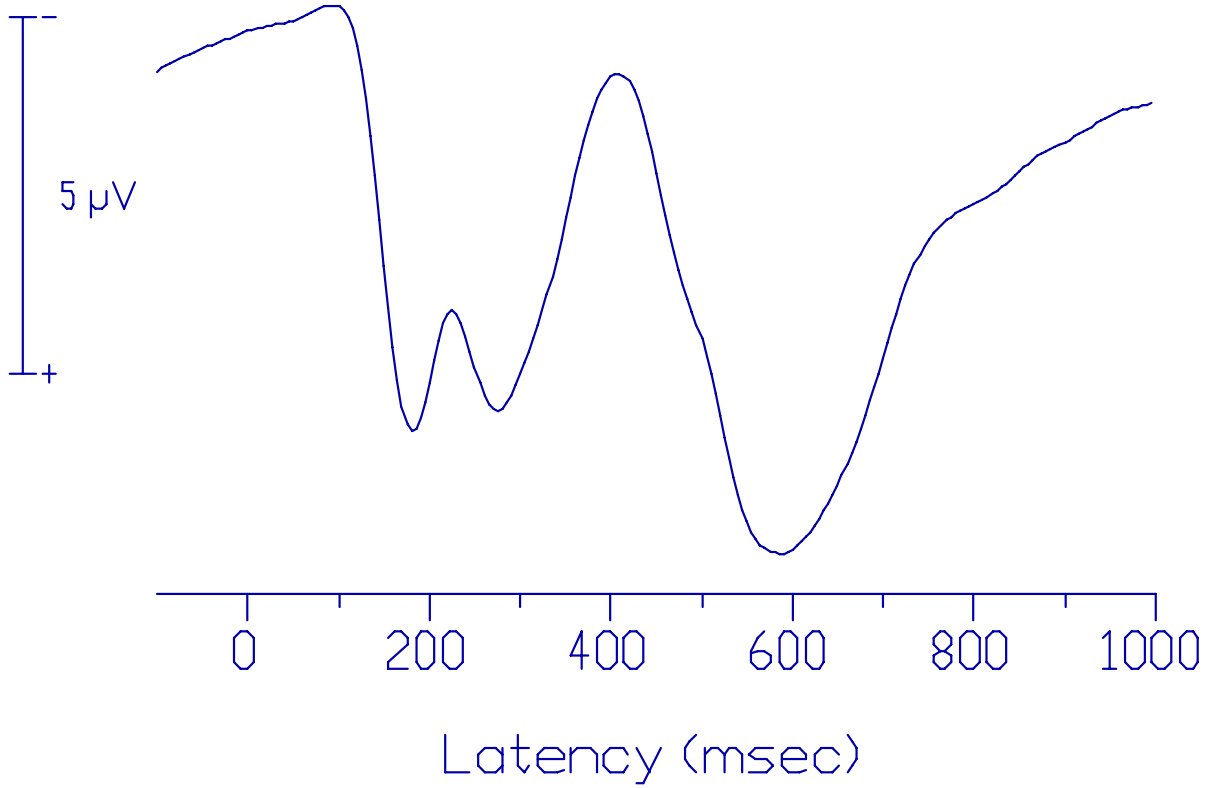
- ERPs 101: Signal averaging

Ongoing EEG



Stimuli

Visual Event-related Potential



Speigel, Cutcomb, Ren, & Pribram. (1985) Journal of Abnormal Psychology

- The study design
  - Very high or very low hypnotizable subjects selected
  - Given three suggestions:
    - Hypnotic enhancement
    - Hypnotic diminution
    - Hypnotic obstruction
  - An additional button-pressing control group

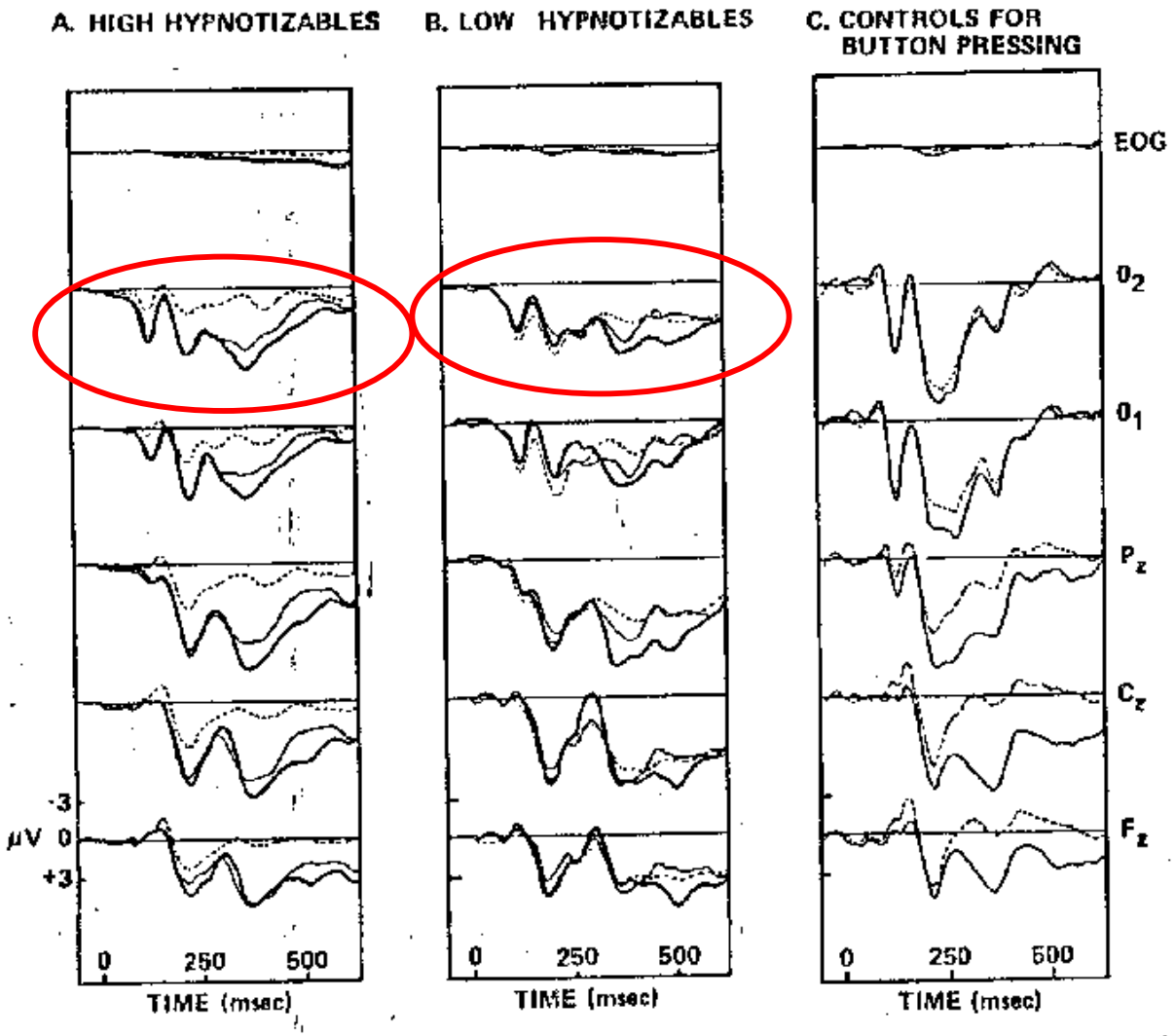


Figure 1. Effect of hypnotic obstructive hallucination on visual evoked potentials. (Visual evoked potentials [VEPs] recorded at leads Fz, Cz, Pz, O_1, and O_2 are expressed as the mean of recordings in each condition from 6 individuals per group yielding approximately 1,800 VEPs per waveform. In A and B, high hypnotizable and low hypnotizable group data shown are VEPs to stimuli observed in the hypnotic enhancement condition [thick solid lines], the hypnotic diminution condition [thin solid lines], and the hypnotic obstructive hallucination condition [dotted lines]. In C, control subjects for button pressing, solid lines are VEPs to stimuli that were all treated as button-pressing targets. Dotted lines are VEPs in a passive attention condition in which all stimuli were treated as standards and required no button pressing.)

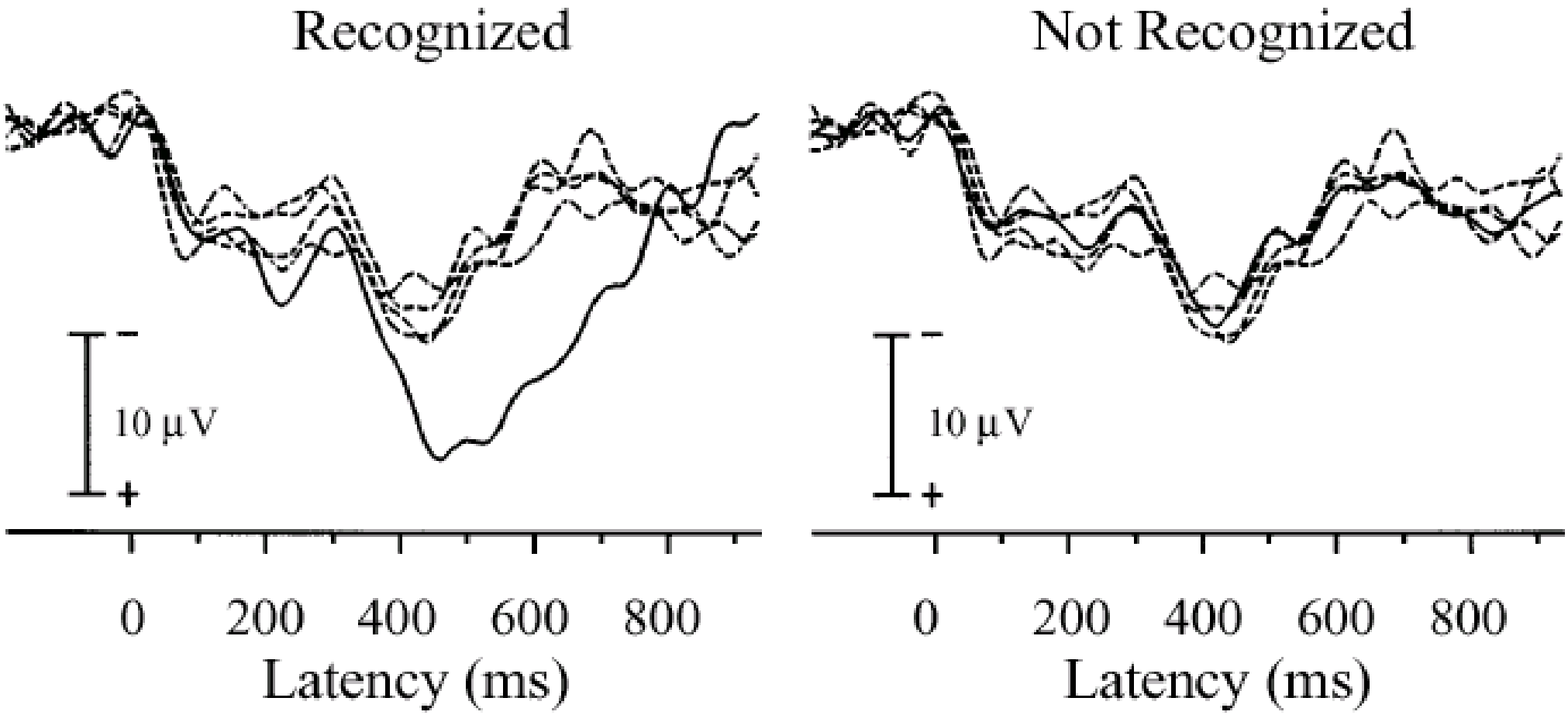
Hypnosis and Speigel continued

- Subsequent study using somatosensory ERPs found that suggestion to block mildly painful stimulus reduce P1 and P3 amplitudes in high- but not low-hypnotizable subjects.
- Also found that suggestions to increase intensity resulted in increase in P1 amplitude, but again, only in the high hypnotizable subjects
- Collectively these studies may suggest alterations at the level of signal detection, not simply interpretation of the signal

Farwell & Donchin (1991) Psychophysiology

- Conventional Polygraphy unacceptably inaccurate
- Rather than rely on autonomic arousal, could rely on a cognitive response of recognition

Rationale


Recognized
Not Recognized
10 μV
10 μV
0
200
400
600
800
0
200
400
600
800
Latency (ms)
Latency (ms)

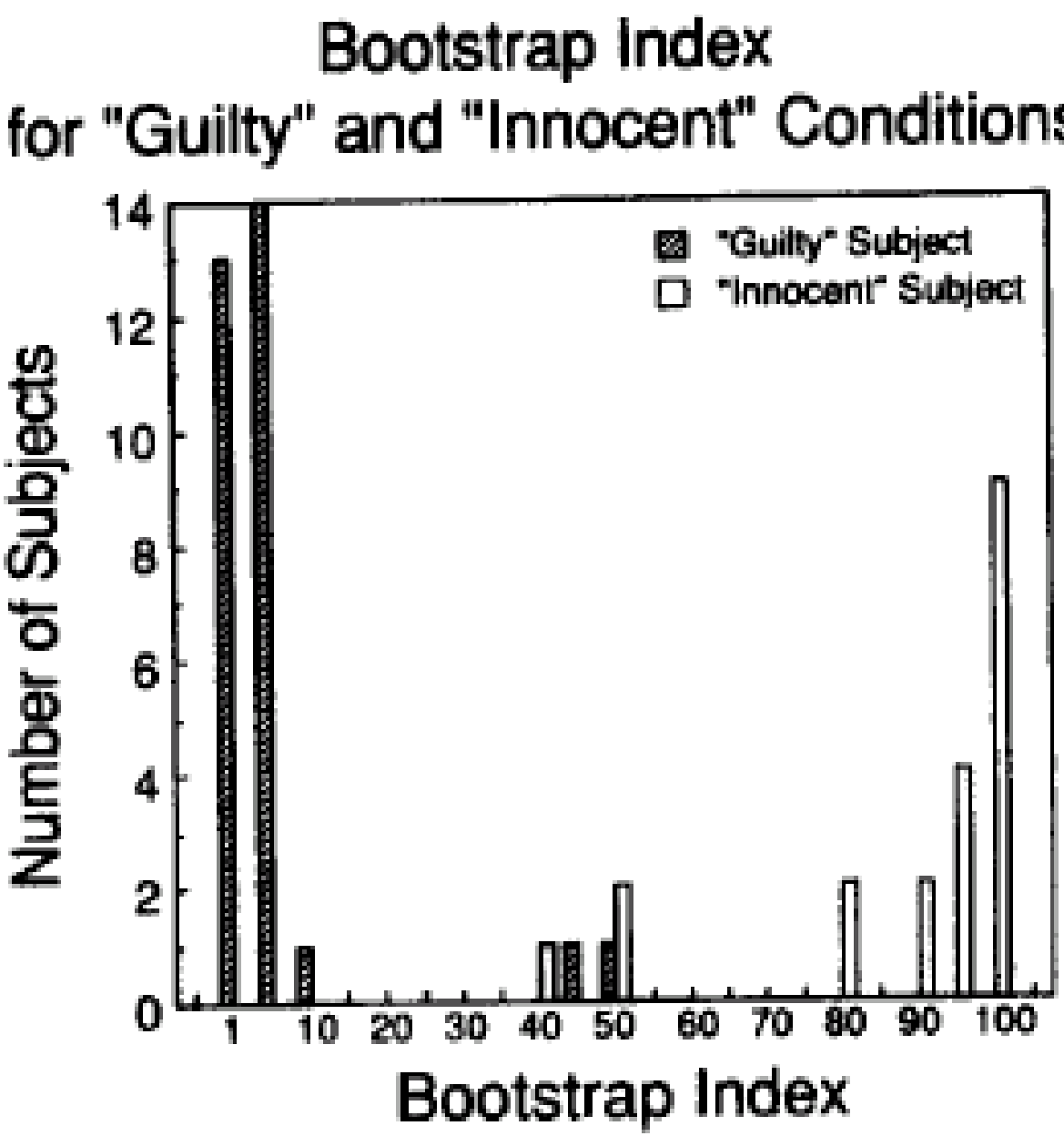


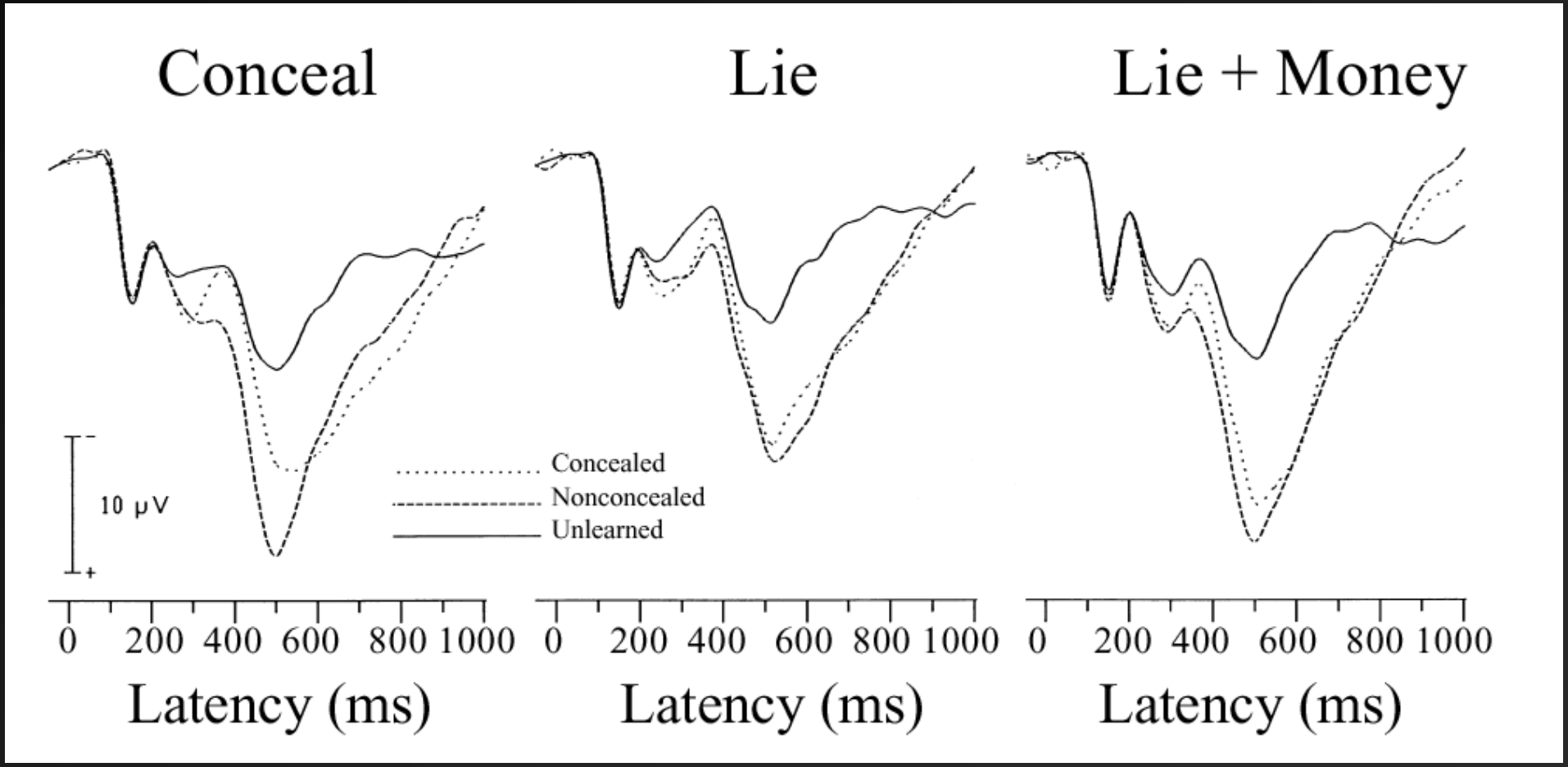
Figure 2. The distribution of the bootstrap statistic for all 40 tests conducted in Experiment 1. Dark bars indicate the number of subjects who were "guilty" and were assigned a given bootstrap value. Light bars show the same data for the "innocent" subjects.

Table 2

2A: ACCURACY OF DETERMINATIONS

Decision	Subject State: Guilty	Subject State: Innocent	Total
Guilty	18	0	18
Innocent	0	17	17
Indeterminate	2	3	5
Total	20	20	40

Allen, Iacono, & Danielson (1992) Psychophysiology



Farwell & Donchin (1988) *Electroencephalography and clinical Neurophysiology*)

- Attempted to develop an applied ERP system for communication without motor system involvement
- For “locked in” patients

CRT Display Used in the Mental Prosthesis

MESSAGE

BRAIN

Choose one letter or command

A	G	M	S	Y	*
B	H	N	T	Z	*
C	I	O	U	*	TALK
D	J	P	V	FLN	SPAC
E	K	Q	W	*	BKSP
F	L	R	X	SPL	QUIT

Fig. 1. CRT display used in the mental prosthesis. The rows and columns of the matrix were flashed alternately. The letters selected by the subject ('B-R-A-I-N') were displayed at the top of the screen in the pilot study.

Operant method (Birbaumer et al.)

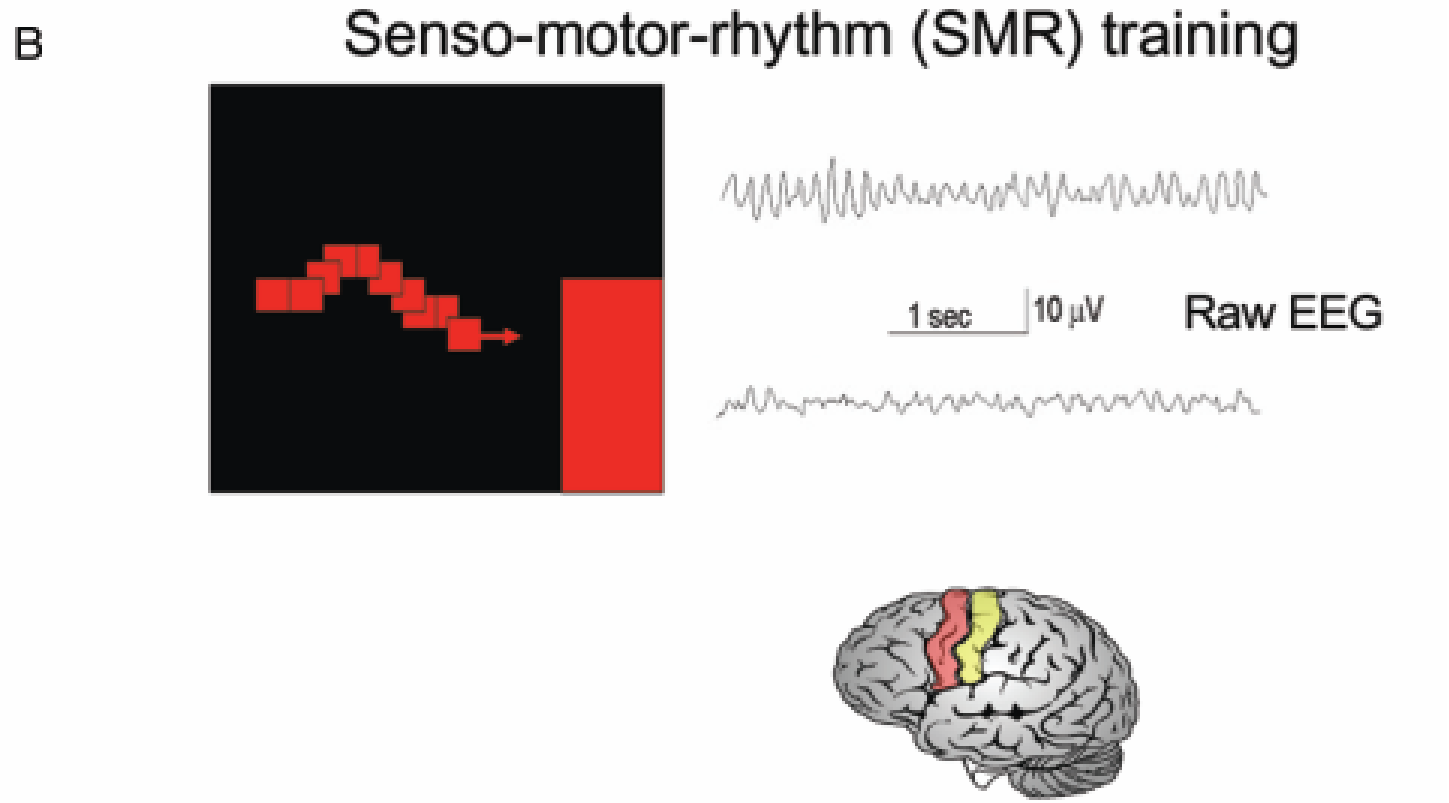
IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 51, NO. 6, JUNE 2004

Brain-Computer Communication and Slow Cortical Potentials

Thilo Hinterberger*, Stefan Schmidt, Nicola Neumann, Jürgen Mellinger, Benjamin Blankertz, Gabriel Curio, and Niels Birbaumer

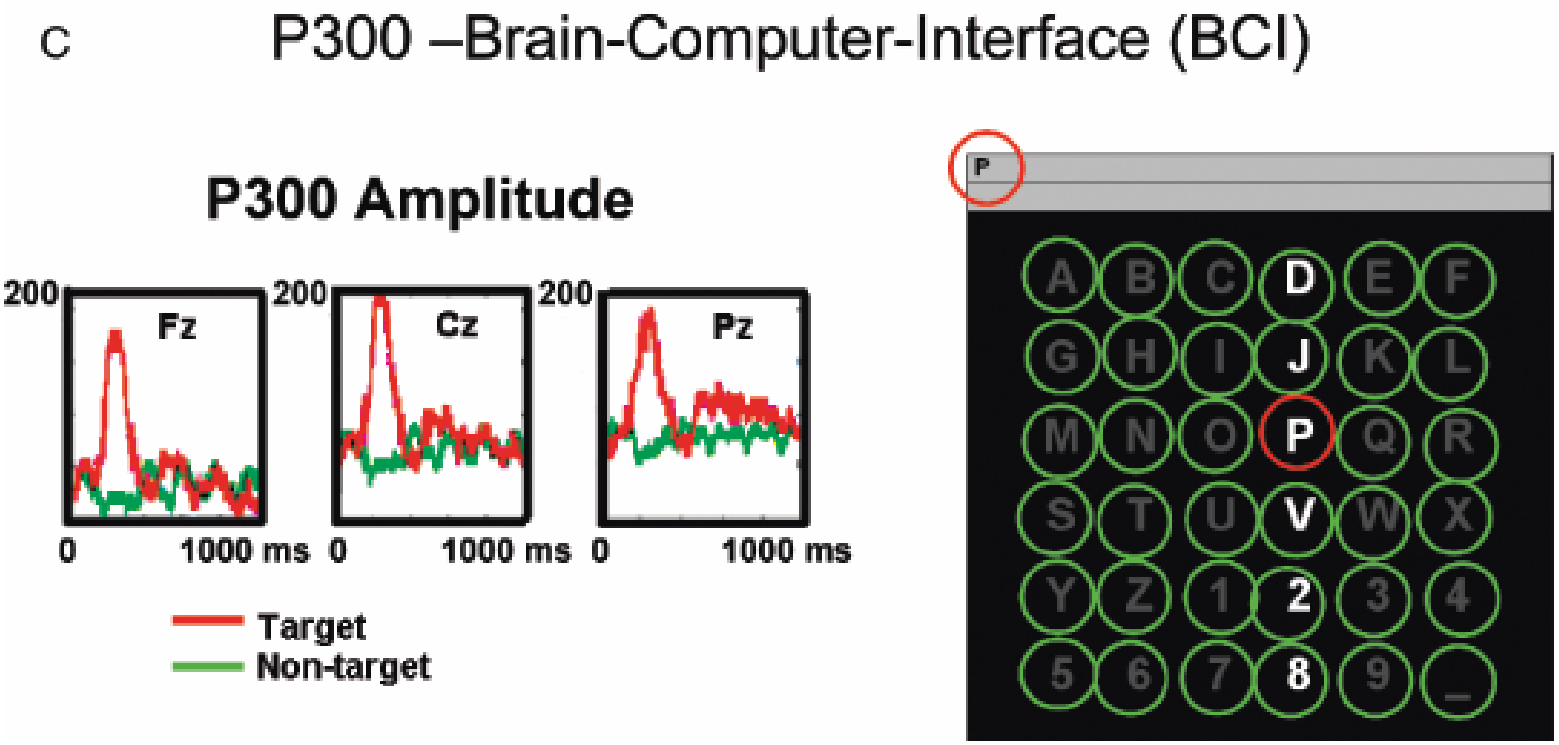
BCI using slow cortical potentials (SCP depicted at the top). Patient selects one letter from the letter string on screen (right below) with positive SCPs, the spelled letters appear on top of the screen

Other Methods (Birbaumer)



Top right: Senso-motor-rhythm (SMR) oscillations fromsensorimotor cortex during inhibition of movement and imagery or execution of movement (EEGtrace below). On the left part of the picture is the feedback display with the target goal on the right side of the screen indicating the required SMR increase (target at bottom) or SMR decrease (target at top). The curser reflecting the actual SMR is depicted in red moving from the right side of the screen toward the target goal.

Other Methods (Donchin)

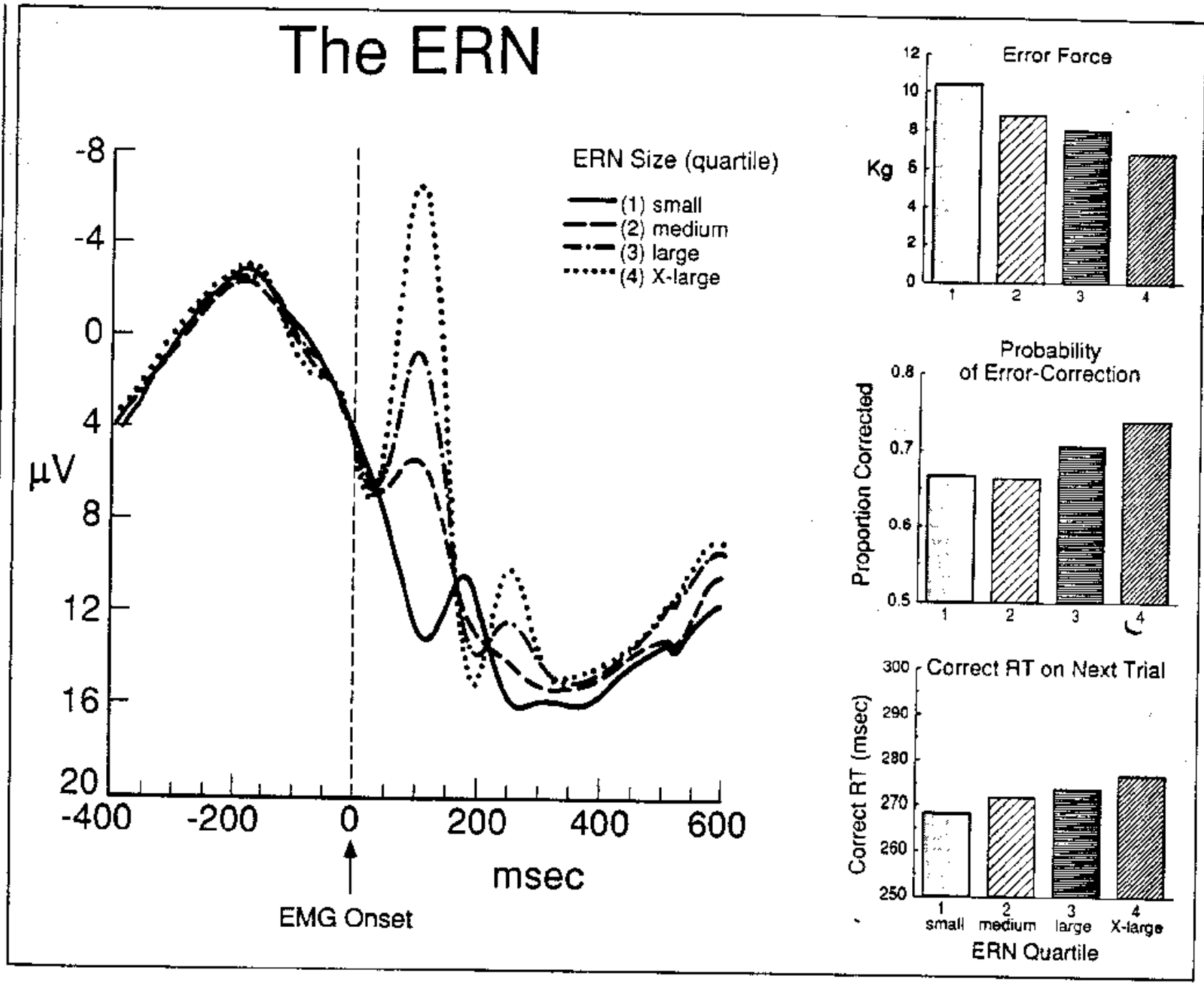


P300-BCI. Rows and columns of letter strings are lighted in rapid succession. Whenever the desired letter (P) is among the lighted string, a P300 appears in the EEG (after Sellers & Donchin 2006; Piccione et al.2006).

Figure from Birbaumer, 2006

Dikman and Allen (2000) Psychophysiology

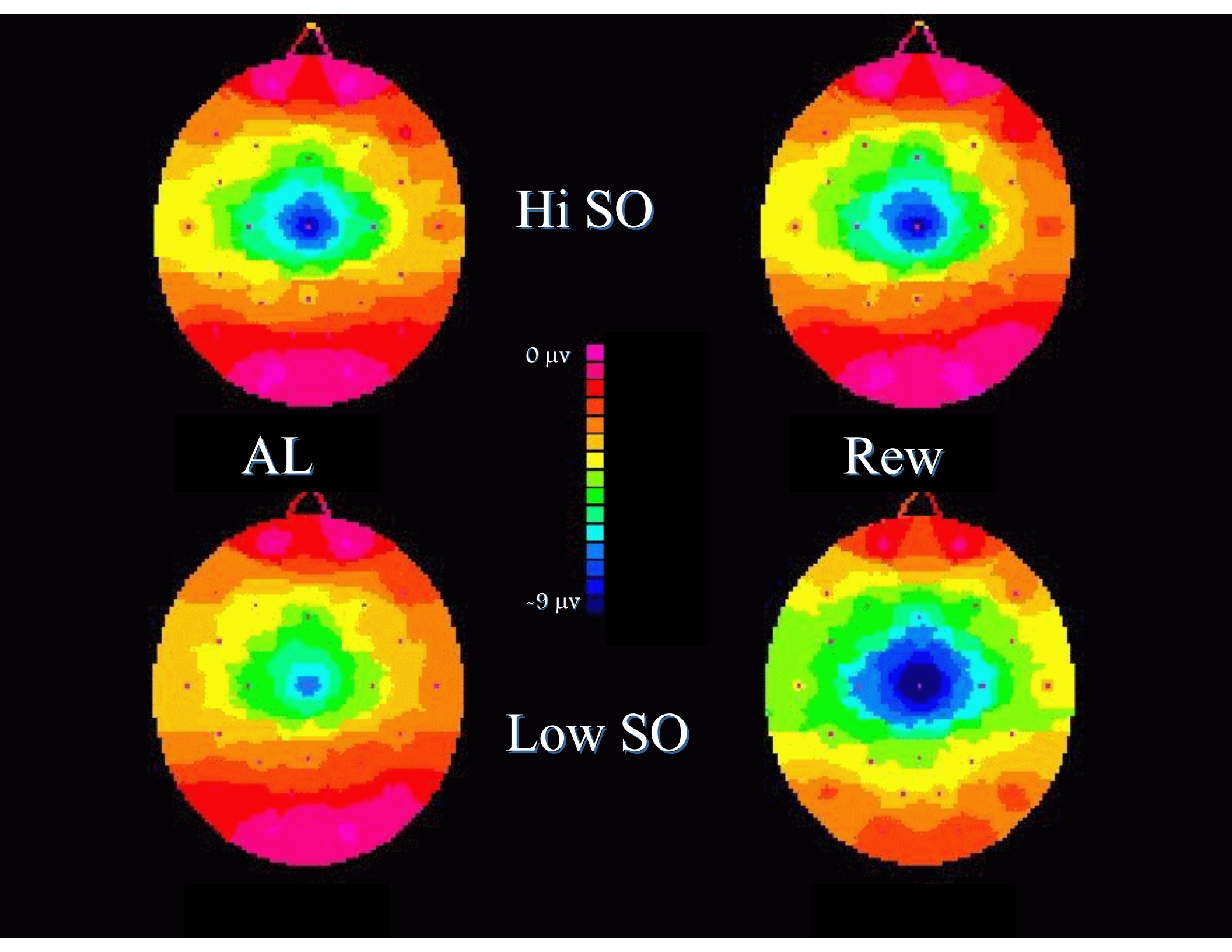
- Avoidance Learning deficits well documented in Psychopathy
- Ascribed by some (e.g. Lykken) to deficient antipatory anxiety in face of potential punishment; ascribed by others (e.g. Kosson) to overfocus on reward
- Autonomic measures (e.g. SCR during countdown to shock task) corroborate the deficient anticipatory anxiety hypothesis
- Would similar phenomenon be evident at level of CNS (i.e. at what stage of processing is there a deficit?)
- Analog Psychopaths participated under conditions of reward and punishment



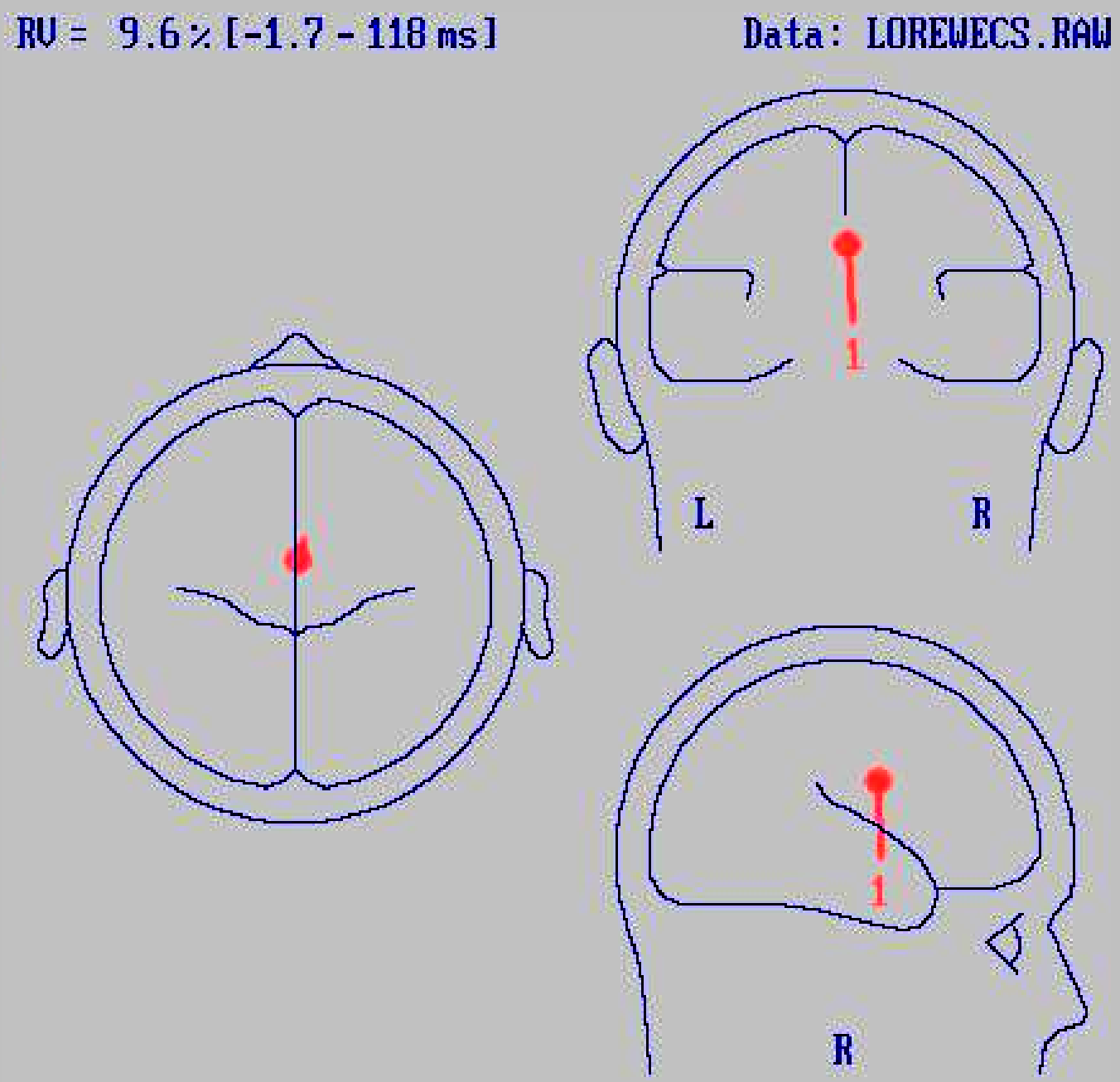
Gehring et al., 1993

Note: Ne by Falkenstein et al., 1990

Fig. 3. Relationship between error-related negativity (ERN) amplitude and three measures of compensatory behavior. Left panel: Average event-related potentials at the C_z electrode as a function of the four levels of the posterior probability measure of ERN amplitude. Right panel, top: Error squeeze force in Kg as a function of the four ERN levels. Right panel, middle: Probability of error correction as a function of the four ERN levels. Right panel, bottom: Correct reaction time on the trial following an error as a function of the four ERN levels.


Hi SO
0 μv
AL
Rew
-9 μv
Low SO

BESA Modeling



Coming Up:

- Next Monday: Reviews of
  - Basic Electricity
  - Basic Neurophysiology and Neuroanatomy

- Don't forget to turn in your 3x5 cards
  - Name
  - Email
  - Section (401 or 501)
  - Questions/Comments